EXECUTIVE SUMMARY

This Draft Environmental Impact Statement (DEIS) for the Mars 2020 mission has been prepared in accordance with the National Environmental Policy Act of 1969, as amended (NEPA), (42 U.S.C. 4321 et seq.); Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions*; the Council on Environmental Quality (CEQ) regulations for Implementing the Procedural Provisions of NEPA (40 CFR parts 1500-1508); and the National Aeronautics and Space Administration's (NASA's) NEPA policy and procedures (14 CFR subpart 1216.3).

This DEIS for the Mars 2020 mission is a tiered document (Tier 2 EIS) under the Mars Exploration Program (MEP). The Mars 2020 DEIS will focus on reasonable alternatives to implement the purpose and need of the Mars 2020 mission and the potential environmental impacts associated with each alternative.

The purpose of this DEIS is to assist in the decision-making process concerning the Proposed Action and Alternatives, including the No Action Alternative, for the proposed Mars 2020 mission planned for launch in 2020. This DEIS provides information associated with potential environmental impacts of implementing a proposed Mars 2020 mission, which would employ new *in situ* scientific instrumentation in order to seek signs of past life, select and store a promising suite of samples in a returnable cache, and demonstrate technology for future robotic and human exploration of Mars. NASA's proposed Mars 2020 mission would use the proven design and technology developed for the Mars Science Laboratory (MSL) rover Curiosity that arrived on Mars in August 2012. Like Curiosity, the proposed Mars 2020 rover would be powered by a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). NASA would select a scientifically important landing site based upon data from past and current missions.

PURPOSE AND NEED FOR ACTION

The purpose of the proposed Mars 2020 mission would be to both conduct comprehensive science on the surface of Mars and demonstrate technological advancements in the exploration of Mars. Mars 2020 mission investigations would reflect several of the high-priority scientific investigations recommended to NASA by the planetary science community. The overall scientific goal would be to address the questions of habitability and the potential origin and evolution of life on Mars.

NASA further characterized these mission objectives in an Announcement of Opportunity (AO) released on 24 September 2013 (NASA 2013d) for the competitive acquisition of payload investigations for the Mars 2020 mission as follows:

- Characterize the processes that formed and modified the geologic record within a field exploration area on Mars selected for evidence of an astrobiologically relevant ancient environment and geologic diversity.
- Perform astrobiologically-relevant investigations on the geologic materials at the landing site.
- Assemble a returnable cache of samples for possible future return to Earth.

- Contribute to the preparation for human exploration of Mars by making significant progress towards filling at least one major Strategic Knowledge Gap (gaps in knowledge or information required to reduce risk, increase effectiveness, and improve the design of robotic and human space exploration missions).

In addition to the objectives identified as part of the AO, NASA would also retain the objective, as identified by the Mars 2020 Mission Science Definition Team, of demonstrating improved technical capabilities for landing and operating on the surface of Mars for the benefit of future Mars missions.

ALTERNATIVES EVALUATED

This DEIS for the Mars 2020 mission evaluates the following alternatives in sufficient detail to make a meaningful comparison of technical feasibility and potential environmental impacts.

- **Proposed Action (Alternative 1) [NASA's Preferred Alternative] —** NASA proposes to continue preparations for and implement the Mars 2020 mission to the surface of Mars. The proposed Mars 2020 spacecraft would be launched on board an expendable launch vehicle from Kennedy Space Center (KSC) or Cape Canaveral Air Force Station (CCAFS), Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020, and would be inserted into a trajectory toward Mars. Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022. The rover proposed for the Mars 2020 mission would utilize a radioisotope power system to continually provide heat and electrical power to the rover's battery so that the rover could operate and conduct science on the surface of Mars.

- **Alternative 2 —** In this Alternative, NASA would discontinue preparations for the Proposed Action (Alternative 1) and implement an alternative configuration for the Mars 2020 mission to Mars. The Mars 2020 rover would utilize solar power as its source electrical power to operate and conduct science on the surface of Mars. The alternative Mars 2020 spacecraft would still be launched on board an expendable launch vehicle from KSC or CCAFS, Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020, and would be inserted into a trajectory toward Mars. Like Alternative 1, should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022.

- **Alternative 3 —** In this Alternative, NASA would discontinue preparations for the Proposed Action (Alternative 1) and implement an alternative configuration for the Mars 2020 mission to Mars. The Mars 2020 rover would utilize solar power as its source of electrical power to operate and conduct science on the surface of Mars. The rover thermal environment would be augmented by the thermal output from Light-Weight Radioisotope Heater Units (LWRHUs) to help keep the rover's onboard systems at proper operating temperatures. The Mars 2020 spacecraft would still be launched on board an expendable launch vehicle from KSC or

CCAFS, Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020, and would be inserted into a trajectory toward Mars. Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022.

- **No Action Alternative** — Under this alternative, NASA would discontinue preparations for the Mars 2020 mission and, in turn, the spacecraft would not be launched.

FUNCTIONAL AND SCIENCE CAPABILITIES AND RISKS

ALTERNATIVES 1, 2, and 3. The Mars 2020 rover designs in both the Proposed Action (Alternative 1) and Alternatives 2 and 3 would carry the same science instruments; therefore, each of the three alternatives would have common mission science objectives. The main difference between these three alternatives is that the radioisotope-powered rover, using an MMRTG, proposed for Alternative 1 would be capable of operating for a full Martian year within a significantly broader range of latitudes on Mars than either of the solar-powered rovers (Alternatives 2 and 3). The capability to land the rover within a broad range of latitudes is important because doing so maintains NASA's flexibility to select the most scientifically interesting location on the surface and would maximize the rover's capability to collect the most desirable surface samples and conduct comprehensive science experiments.

A pure solar mission (Alternative 2), with current state-of-the-art solar arrays that remain 40 percent dust free[1] with MSL heritage avionics and mechanical systems (e.g., actuators) would not be feasible for an entire Martian year at any latitude. If one assumes that the solar arrays would remain 70 percent free of dust, then a mission would be possible at a narrow band of southern latitudes between 0-5^{o} degrees. With current dust mitigation technology, operation over a larger latitude range for an entire year is not possible. To extend the range of operations, new dust mitigation technology would require development and flight certification.

A solar mission with the same state-of-the-art solar arrays, the same assumption that the solar arrays remain 40 percent free of dust, and the addition of LWRHUs (Alternative 3), allow for some half-year missions in northern latitudes as well as a full year constrained mission in a latitude band between 5-20^{o} south latitude. The drawback of the southern latitude missions is that periods of constrained science operations and hibernation would be necessary. In hibernation, all science operations would be halted and only activities needed for the rover to survive would be performed. If one assumes that the solar arrays remain 70 percent free of dust, then a mission would be possible between 20^{o} south and 20^{o} north latitudes. Even with this improved operating range, there would be periods of constrained science operation and hibernation.

[1] Note that of the solar-powered Mars Exploration Rovers (MERs), Opportunity has remained at least 40% dust free for the entire mission to date, while Spirit experienced high dust accumulation following a global dust storm; and at one point in the mission had less than 25% dust free solar arrays.

Any of the solar-powered mission architectures would be expected to increase the technical risk and resulting cost of mission design and development. A number of design changes (modifications from the Curiosity heritage design) would also be necessary to modify the rover's power control electronics. Small increases in rover mass on the order of less than10 kilograms (22 pounds) may also be expected relative to the baseline MMRTG powered rover, primarily in the area of the solar array support structure. The rover's thermal design would have to be amended as well, since survival heating would be provided by electrical output as opposed to any use of the MMRTG thermal energy. The changes required to accommodate solar power for the Mars 2020 rover could potentially impact the accommodation of science instruments for the mission.

Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022. The science potential associated with Alternatives 1, 2, and 3 with a 2022 launch would be similar to those projected for each alternative with a 2020 launch. Under all circumstances, an MMRTG-powered rover would provide more power and heat for science activities.

No Action Alternative. Under the No Action Alternative, NASA would discontinue preparations for the Mars 2020 mission and the spacecraft would not be launched. Therefore, none of the recommended science objectives would be met.

ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION AND THE ALTERNATIVES

For the proposed Mars 2020 mission, the potentially affected environment would include the areas on or near the vicinity of the launch site and portions of the global environment. For each of the alternatives, the potential non-radiological and radiological environmental consequences of launch site preparation for and launch of the Mars 2020 mission are summarized below. The non-radiological consequences associated with Alternatives 1, 2, and 3 have been addressed in prior U.S. Air Force (USAF) and NASA environmental documents (NASA 2011, USAF 2000). DOE's preparation of an MMRTG or LWRHUs for the proposed Mars 2020 mission would be very similar to their process in preparing the nearly identical MMRTG for the MSL mission. The environmental impacts of preparing an MMRTG by the DOE for the Mars 2020 mission have already been evaluated in existing DOE NEPA documents (DOE 1993, 2000, 2002, 2002b, 2008, 2013).

The evaluations presented in this DEIS are based on representative configurations of Atlas V, Delta IV Heavy, and the Falcon Heavy class of expendable launch vehicles. NASA considers these evaluations to adequately bound the potential environmental consequences of the alternatives described in this DEIS.

Environmental Impacts of a Normal Mission

Alternatives 1, 2, and 3. The environmental impacts associated with successfully implementing either the Proposed Action (Alternative 1), Alternative 2, or Alternative 3 would principally be with the exhaust emissions from the launch vehicle. These impacts were addressed in the *Final Environmental Assessment for Launch of NASA Routine Payloads on Expendable Launch Vehicles* (Routine Payload EA) (NASA 2011) for all candidate launch vehicles. These effects would include short-term impacts on air quality from the exhaust cloud at and near the launch pad, and short-term acidic deposition on the vegetation and surface water bodies at and near the launch complex. These effects would be transient and there would be no long-term or cumulative impacts to the environment. Some short-term ozone degradation would occur along the flight path of the vehicle as the vehicle passes through the stratosphere and deposits ozone-depleting chemicals (primarily hydrogen chloride) from its solid rocket boosters. These effects would be transient and no long-term or cumulative impacts to the ozone layer would be expected (USAF 2000).

No Action Alternative. There would be no environmental impacts associated with the No Action Alternative.

Non-Radiological Environmental Impacts of Potential Launch Accidents

Alternatives 1, 2, and 3. Non-radiological accidents could occur during preparation for and launch of the Mars 2020 spacecraft at the KSC or CCAFS. As with the impacts associated with a successful launch, these impacts were addressed in the *Final Environmental Assessment for Launch of NASA Routine Payloads on Expendable Launch Vehicles* (Routine Payload EA) (NASA 2011) for all candidate launch vehicles. The two non-radiological accidents of principal concern for the proposed Mars 2020 mission would be a liquid propellant spill associated with fuel loading operations and a launch vehicle accident. Propellant spills or releases would be minimized through standard remotely operated actions that close applicable valves and safe the propellant loading system. Propellant loading would occur only shortly before launch, further minimizing the potential for accidents.

Range Safety at CCAFS uses models based on dozens of past launches over many years to predict potential launch hazards to the public and to launch site personnel prior to a launch. These models are used to calculate the risk of injury resulting from exposure to potentially toxic exhaust gases from normal launches, and from exposure to potentially toxic concentrations of propellant, blast overpressure, or debris due to a failed launch. A launch could be postponed if the predicted collective risk of injury from exposure to toxic gases, blast overpressure, or debris, exceeds acceptable established limits (USAF 2004).

A launch vehicle accident on or near the launch area during the first few seconds of flight could result in the release of the propellants onboard the launch vehicle and the spacecraft. The resulting emissions from the combusted propellants would chemically resemble those from a normal launch. Debris would be expected to fall on or near the launch pad or into the Atlantic Ocean. Modeling of postulated accident consequences with meteorological parameters that would result in the greatest concentrations of emissions over land areas (as reported in previous USAF environmental documentation (NASA 2011)) indicates that the emissions would not reach levels threatening public health. As indicated above, Range Safety confirms prior to launch that public safety would be assured even in the event of a launch accident.

No Action Alternative. Under the No Action Alternative, NASA would not complete preparations for the Mars 2020 mission. The No Action Alternative would not involve any of the environmental impacts associated with potential launch-related accidents.

Potential Radiological Environmental Impacts of Launch Accidents

A principal concern associated with the launch of the proposed Mars 2020 mission involves potential launch vehicle (LV) accidents that could result in the release of some of the radioactive material onboard the spacecraft. Under Alternative 1, the Mars 2020 rover electrical power would be supplied by one MMRTG, which would use the natural decay of its radioisotope fuel to produce electricity. The MMRTG contains 4.8 kg (10.6 lb), or approximately 60,000 curies, of plutonium dioxide (consisting primarily of plutonium-238). Alternative 3 complements the power from solar arrays with up to 71 LWRHUs, each containing a pencil eraser-sized pellet of approximately 2.7 grams, or (a total of 192 grams (0.42 lb)), 33 curies (a total of 2,300 curies), of plutonium dioxide (also primarily plutonium-238). In addition, the rover designs proposed for alternatives 1, 2, and 3 for the Mars 2020 mission may incorporate science instruments that make use of small quantities of radioisotope sources. Alternative 2 would not involve any radioactive material other than what may be used in selected science instruments.

The U.S. Department of Energy (DOE) provides the MMRTG/LWRHUs for the Mars 2020 mission and would retain responsibility for the plutonium during both the preparation and launch of the mission and in the event of a launch accident. As a cooperating agency, DOE has prepared the *Nuclear Risk Assessment for the Mars 2020 Mission Environmental Impact Statement* (SNL 2014). The nuclear risk assessment for the Mars 2020 mission considers: (1) potential accidents associated with the launch, their probabilities and accident environments; (2) the response of the MMRTG, LWRHUs, and science instrument sources to such accidents in terms of the release probabilities and estimated amounts and form of radioactive material released; and (3) the radiological consequences and risks associated with such releases.

Information on potential launch vehicle accident scenarios and related probabilities was developed by NASA based on information provided by the potential launch service providers and the spacecraft provider. DOE then assessed the response of the MMRTG, LWRHUs, and the science instrument radionuclides to these accident environments, and estimated the amount of radioactive material that could be released. Finally, DOE determined the potential consequences of each release to the environment and to the potentially exposed population. Accidents were assessed over all mission launch phases—from pre-launch operations through escape from Earth orbit—and consequences were assessed for both the regional population near the launch site and the global population.

Results of the risk assessment for this DEIS show that the most likely outcome of implementing the Proposed Action (Alternative 1) would be a successful launch with no release of radioactive materials. However, the risk assessment did identify potential launch accidents that, while not expected, could result in a release of radioactive material in the launch area for accidents occurring early in the launch, in southern Africa for events resulting in a suborbital reentry, and in other global locations following orbital reentry. In each of these regions, the probability of an accident resulting in a release of radioactive material would be, at worst, 1 in 150 for the instrumentation radiological sources, 1 in 3,800 for the MMRTG, and 1 in 16,000 for the LWRHUs.

The radiological impacts for each postulated accident were calculated in terms of (1) impacts to individuals in terms of the maximum individual dose (the largest expected dose that any person could receive for a particular accident); (2) impacts to the population in terms of the potential for additional latent cancer fatalities due to a radioactive release (i.e., cancer fatalities that are in excess of those latent cancer fatalities which the general population will normally experience from all causes over a long-term period following the release); and (3) impacts to the environment in terms of land area contaminated at or above specified levels. The analysis conservatively assumes no mitigation actions, such as sheltering and exclusion of people from contaminated land areas. NASA would develop a Radiological Contingency Plan that would be implemented in the event of an accident. This plan would identify mitigation actions designed to minimize radiological impacts.

Potential environmental contamination was evaluated in terms of areas exceeding various specific screening levels and dose-rate-related criteria. For this DEIS, land areas would be considered to be contaminated to the point of requiring detailed characterization for potential cleanup actions when radiological deposition exceeds a screening level of 0.2 microcuries per square meter ($\mu Ci/m^2$) (SNL 2014).

Should any active decontamination be required, the costs associated with these efforts could vary widely depending upon the characteristics of the contaminated area and its size. Previous estimates by the Environmental Protection Agency (EPA), adjusted for inflation to 2013 dollars, for general land/water radiological cleanup, range from $110 million to $600 million per square kilometer or about $285 million to $1.6 billion per square mile) (Chanin et al. 1996).

Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022. Since this launch period is in a similar season as the 2020 launch period, the projected radiological impacts would be similar, with only a small increase in population impacts due to population growth. Thus, within the overall uncertainties, the radiological impacts associated with a 2022 launch would be the same as those for the proposed 2020 launch.

Alternative 1: As shown in Figure ES-1, the most probable outcome is a successful launch. In the event of a launch accident, most accidents do not result in the release of plutonium dioxide. Between one and two percent of the launch accidents do however result in a release. These accidents may occur near the launch area, resulting in a release within the launch area; or they may occur later in the launch and result in a release beyond the launch area. The risk assessment shows that for the Mars 2020 mission using an MMRTG:

- There is a 97.5% chance of a successful launch.
- There is a 2.5% chance of a launch accident.
- There is a 1 in 2,600 chance of a launch accident that would release plutonium dioxide.
  - There is a 1 in 11,000 chance of a launch accident that would result in a release of plutonium dioxide in the launch area.
  - There is a 1 in 3,500 chance of a launch accident that would result in a release of plutonium dioxide outside the launch area.
- No radiological fatalities would be expected to occur as a result of any accident.
- The average maximum dose to any member of the public from an accident with a release would be equal to about 3 months of exposure to natural background radiation for a person living in the United States.

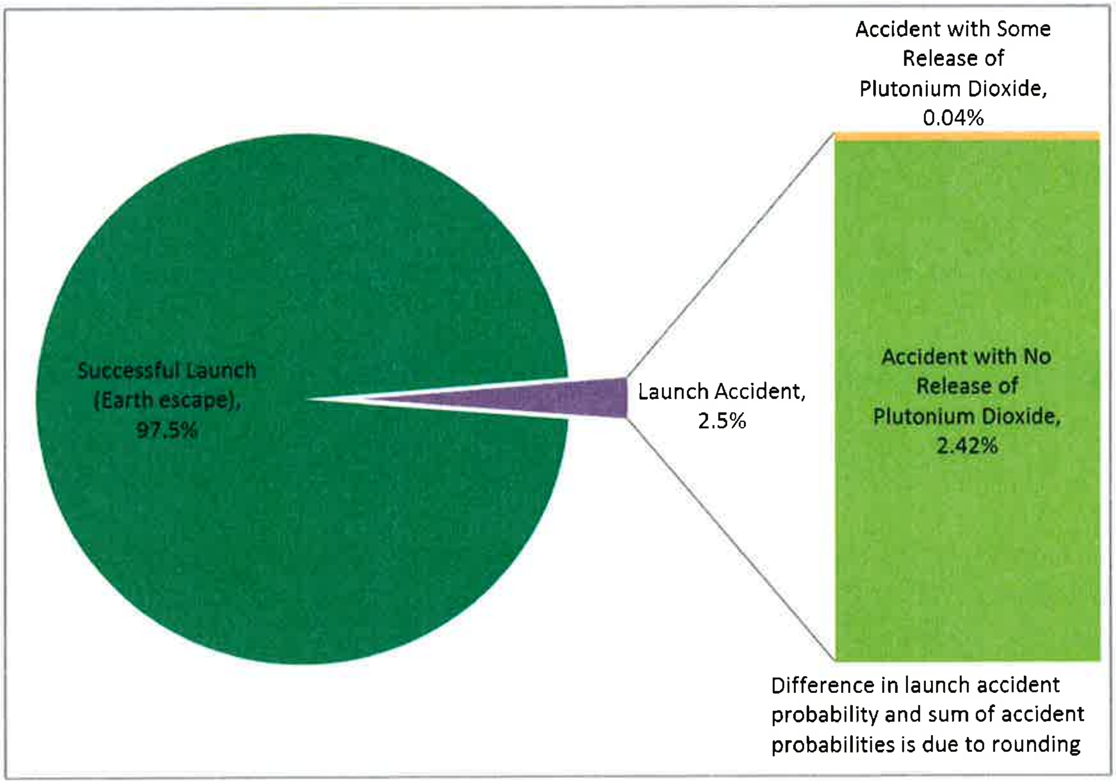

Figure ES-1: Alternative 1 - MMRTG Accident Probabilities

The accident probabilities and mean consequences are the result of the summation of individual accidents that have a wide range of consequences and probabilities. For launch-related issues that could occur prior to launch, the most likely result would be a safe hold or termination of the launch countdown with no radiological consequences. After lift-off, most accidents would lead to activation of safety systems that would result in automatic or commanded destruction of the launch vehicle.

For post launch accidents near the launch area that result in a radiological release, the predicted mean radiological dose to the maximally exposed individual would be about 0.06 rem. The probability for such an accident is about 1 in 11,000. No near-term radiological health effects would be expected from such an exposure. Each exposure would, however, yield an increase in the statistical likelihood of a latent cancer fatality over the long term. For a launch area accident resulting in a release, a mean of 0.29 additional latent cancer fatalities could occur among the potentially exposed members of the local and global populations.

The risk assessment concludes that the average land contamination above 0.2 $\mu Ci/m^2$ for all launch area accidents that result in a release is 7.4 km^2 (less than three square miles).

For accidents that occur prior to or shortly after the spacecraft reaches Earth orbit for which debris could impact land, the total probability of an accident resulting in a release during this phase is about 1 in 68,000. The maximum (mean value) dose received by an individual close to the impact site would be about 0.043 rem. The collective dose received by all individuals within the potentially exposed global population would result in about 0.20 mean additional latent cancer fatalities within the exposed population.

For accidents after the spacecraft reaches Earth orbit during which debris could impact land, the total probability of an accident resulting in a release is about 1 in 3,800. The maximum (mean value) dose received by an individual close to the impact site would be about 0.0005 rem. The collective dose received by all individuals within the potentially exposed global population would result in about 0.0026 mean additional latent cancer fatalities within the exposed population.

Considering all launch accidents assessed in this DEIS, the maximally exposed member of the exposed population faces a much less than 1 in a million chance of incurring a latent cancer due to a launch failure of the Mars 2020 mission.

Alternative 3: Under Alternative 3 the Mars 2020 rover would utilize solar energy as its primary source of electrical power. Alternative 3 would not involve any MMRTG-associated radiological risks. However, NASA may consider the use of up to 71 LWRHUs to provide additional heat to help maintain the solar-powered rover's functionality during extreme cold temperature conditions. The use of LWRHUs for this alternative could also result in mission risks and related radiological consequences.

As shown in Figure ES-2, the most probable outcome is a successful launch. In the event of a launch accident, most accidents do not result in the release of plutonium dioxide. Less than one percent of the launch accidents do however result in a release. These accidents may occur near the launch area, resulting in a release within the launch area; or they may occur later in the launch and result in a release beyond the launch area. The risk assessment shows that for the Mars 2020 mission using LWRHUs:

- There is a 97.5% chance of a successful launch.
- There is a 2.5% chance of a launch accident.
- There is a 1 in 15,000 chance of a launch accident that would release plutonium dioxide.
    - There is a 1 in 16,000 chance of a launch accident that would result in a release of plutonium dioxide in the launch area.

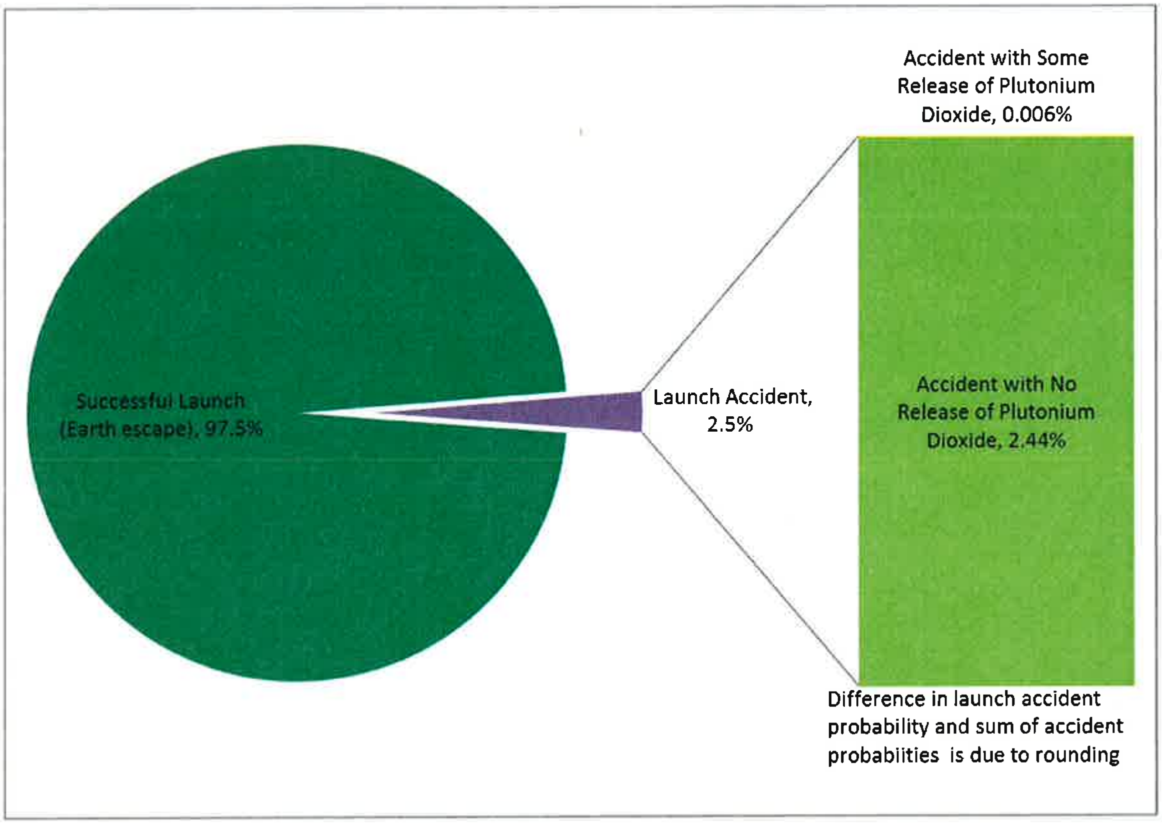

Figure ES-2: Alternative 3 - LWRHU Accident Probabilities

  - There is a 1 in 420,000 chance of a launch accident that would result in a release of plutonium dioxide outside the launch area.
- No radiological fatalities would be expected to occur as a result of any accident.
- The average maximum dose to any member of the public would be equal to about 5 days of exposure to natural background radiation for a person living in the United States.

Most of the radiological accident impacts for Alternative 3 would be associated with accidents that occur on or near the launch area. The LWRHUs would be expected to survive most launch accidents beyond the immediate launch area without releasing any plutonium dioxide. For accidents near the launch area that result in a radiological release, the predicted mean radiological dose to the maximally exposed individual would be about 0.004 rem. The probability for such an accident is about 1 in 16,000. No near-term radiological health effects would be expected from such an exposure. Each exposure would, however, yield a small increase in the statistical likelihood of a latent cancer fatality over the long term. For a launch-area accident with a release, a mean of 0.020 additional latent cancer fatalities could occur among the potentially exposed members of the local and global populations.

The risk assessment concludes that the average land contamination above 0.2 $\mu Ci/m^2$ for all launch area accidents that result in a release is 0.51 km^2 (less than a quarter of a square mile).

Considering all of the launch accidents assessed in this DEIS, the maximally exposed member of the exposed population faces a much less than 1 in a million chance of incurring a latent cancer due to a failure of the Mars 2020 mission.

Alternatives 1, 2 and 3: Scientific Instrument Small Quantity Radiological Sources. The risks associated with small quantity radiological sources would be applicable to all of the alternatives (with the exception of the No Action Alternative) being considered for the Mars 2020 mission. While the quantity of radioactive material used for any instrument would be much smaller than that contained in either the MMRTG or the LWRHUs, this material would be much more likely to be released in an accident. The release probabilities are typically higher, roughly ten times or more, than those for the MMRTG or LWRHUs. The post-launch accident in the vicinity of the launch area has a probability of release of 1 in 1,700 compared to the 1 in 16,000 (LWRHUs) or 1 in 11,000 (MMRTG).

The percentage of the material released would also be higher for the small quantity instrument sources compared to the MMRTG or LWRHUs. However, since there is considerably less radioactive material present, the subsequent impacts would be much smaller. Maximally exposed individual doses for each launch phase are in the 0.00001 rem range and the potential health effects are less than 0.0003 additional latent cancer fatalities, much smaller than the corresponding values for accidents involving either the MMRTG or LWRHUs. These competing factors (higher probability, lower consequence) result in the risks associated with these small quantity sources being comparable to those identified for the LWRHUs (Alternative 3).

No Action Alternative. Under the No Action Alternative, NASA would not complete preparations for and implement the Mars 2020 mission. The No Action Alternative would not involve any of the radiological risks associated with potential launch accidents.

SUMMARY COMPARISON OF THE ALTERNATIVES

Table ES-1 presents a summary comparison of the Proposed Action (Alternative 1), Alternative 2, Alternative 3, and the No Action Alternative in terms of each alternative's capabilities for operating and conducting science on the surface of Mars, the anticipated environmental impacts of normal implementation of each alternative, and the potential environmental impacts in the event of an unlikely launch accident for each alternative.

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Table ES-1. Summary Comparison of the Mars 2020 Mission Alternatives

	Proposed Action (Alternative 1)	Alternative 2	Alternative 3	No Action Alternative
Rover Power Alternative	MMRTG	Solar Array no LWRHUs	Solar Array with LWRHUs	Not applicable
Functional Capability	Capable of operating for at least one Mars year at landing sites between 30° north and 30° south latitudes on Mars	Unable to operate for a full Mars year at any latitude[a]	Limited-lifetime capability for operating at landing sites between 20° south and 5° south latitudes on Mars[a]	Not applicable
Science Capability	Capable of accomplishing all science objectives at any scientifically desirable landing site between 30° north and 30° south latitudes	Capable of accomplishing up to 33% of science objectives during partial year operation at limited latitudes[b]	Capable of accomplishing up to 70% of science objectives at limited latitudes[b] due to constrained operations during northern winter	No science achieved
Anticipated Environmental Impacts	Short-term impacts associated with exhaust emissions from the launch vehicle during a normal launch	Short-term impacts associated with exhaust emissions from the launch vehicle during a normal launch	Short-term impacts associated with exhaust emissions from the launch vehicle during a normal launch	No impacts
Potential Environmental Impacts in the Event of a Launch Accident	Potential impacts associated with combustion of released propellants and falling debris Potential radiological impacts associated with release of small quantity radioisotopes from science instruments and release of some of the plutonium dioxide from the MMRTG	Potential impacts associated with combustion of released propellants and falling debris Potential radiological impacts associated with release of small quantity radioisotopes from science instruments	Potential impacts associated with combustion of released propellants and falling debris Potential radiological impacts associated with release of small quantity radioisotopes from science instruments and release of some of the plutonium dioxide from the LWRHUs	No potential impacts

(a) These numbers assume a dust factor of 40%. Assuming dust mitigation technology improvements on the Mars Exploration Rover solar array performance, the rover (without LWRHUs) is estimated to survive for a full year at latitudes between 0° and 5° south and, with LWRHUs, full year constrained operation between 20° south and 15° north latitudes is possible.

(b) Improved solar array performance from dust mitigation technology would result in a corresponding increase in science capability, expanding the range of latitudes the rover could operate for a full year.

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